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Citation for published version:

Stamatakis, E, Kelly, P, Strain, T, Murtagh, E, Ding, D & Murphy, MH 2018, 'Self-rated walking pace and all-cause, cardiovascular disease, and cancer mortality: individual participant pooled analysis of 50,225 walkers from 11 population British cohorts', *British Journal of Sports Medicine*, vol. 50, no. 12, bjsports-2017-098677.R1, pp. 1-8. <https://doi.org/10.1136/bjsports-2017-098677>

Digital Object Identifier (DOI):

[10.1136/bjsports-2017-098677](https://doi.org/10.1136/bjsports-2017-098677)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

British Journal of Sports Medicine

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TITLE

Self-rated walking pace and all-cause, cardiovascular disease, and cancer mortality:
individual participant pooled analysis of 50,225 walkers from 11 population British cohorts

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Word Count

Abstract: 254

Main Text: 3079

ABSTRACT

Background/Objectives: Walking pace is associated with risk of premature mortality.

However, whether this relationship is independent of total volume of physical activity and highest physical activity intensity reached remain unclear. We examined the associations between walking pace and cause-specific mortality, investigating the potential modifying effect of factors such as total physical activity volume, highest physical activity intensity, age, sex and BMI.

Methods: Prospective pooled analysis of 11 population-based baseline surveys in England and Scotland between 1994-2008 that were linked with mortality records. Multivariate-adjusted Cox proportional hazards models examined associations between walking pace (slow, average, brisk/fast) and all-cause, cancer, and CVD mortality.

Results: 50,225 walkers were entered in the core analyses. Among participants who did not experience an event in the first two years of follow up (n=49,731), walking at an average or brisk/fast pace was associated with a reduced risk of all-cause mortality (20% (95%CI=12-28%) and 24% (95%CI=13-33%) respectively) and CVD mortality (24% (95%CI=9-36%) and 21% (95%CI=1-38%) respectively) mortality, compared to reporting walking at a slow pace. In stratified analyses, such associations were evident amongst those over 50 years, those not meeting the physical activity recommendations, and those who did not undertake vigorous intensity activity. There was no interactions by sex or BMI. No associations were seen between pace and cancer mortality.

Conclusion: Walking i benefits health. Assuming causality, these analyses suggest that increasing walking pace could reduce risk for all-cause and CVD mortality. Walking pace could be emphasised in public health messages, especially in situations when increase in walking volume or frequency is less feasible.

Keywords

Walking, physical activity, mortality, walking pace, epidemiology, public health,
cardiometabolic, cohort studies

INTRODUCTION

Increasing population level walking remains a key focus of physical activity (PA) promotion. Regular walking is known to confer many physical, mental and social health benefits.¹ Meta-analyses of cohort studies have sought to quantify the association between regular walking and reduction in risk for all-cause mortality (ACM).²⁻⁴ Kelly et al., (2014) estimated that after adjustment for other PA, walking at a volume equivalent to PA guidelines was associated with an 11% reduction in risk for ACM compared to no walking.⁵

Considering specific health endpoints, cardiovascular disease (CVD) and cancer are the two most common avoidable causes of mortality in the UK.⁶ Hamer and Chida (2008) conducted a meta-analysis of 13 cohort studies and found a 31% reduction in risk of CVD mortality in the highest walking categories compared with the lowest walking volume/intensity category.² A recent, large analysis of over 250,000 adults in the UK found walking commuting was associated with a 36% reduction in risk of CVD mortality compared to non-active commuting.⁷ The results for cancer mortality are less clear, with, for example, Matthews et al., (2007) and Celis-Morales (2017) finding no significant associations between walking volume and cancer mortality in large cohort studies.^{7 8}

According to principles of overload, a higher relative activity intensity achieved by a faster pace of walking would provide the stimulus to produce a greater physiological response, and more substantial or even additional health benefits. Acute studies have shown that walking at a faster pace results in greater physiological responses¹. However, while total volume of walking e.g. by distance or time has been frequently studied²⁻⁵, less is known about the long-term health effects of habitual walking pace.

A Copenhagen City Heart Study analysis⁹ reported reduced risk of heart failure for moderate and high walking speed compared to slow speed. The authors also suggested that walking pace may have a stronger association with heart failure than total duration of walking. Manson et al.,¹⁰ found that among 73,743 postmenopausal women aged 50-79 years walking pace was associated with reduced incidence of CVD in a dose-response fashion. In a 40-year follow up of the Whitehall study of 6,981 British civil servants, Batty et al.,¹¹ compared slow walking pace to high walking pace and found a reduced risk of all-cause, coronary heart disease (CHD), and total cancer mortality. None of these studies adjusted for total volume of PA and it is therefore unclear if the reported effects were partly attributable to the higher overall activity levels of brisk/fast walkers.

A recent analysis of 420,000 UK Biobank Participants found significant associations between higher walking pace and reduced risk of all-cause and CVD mortality, but inconsistent findings for cancer mortality¹². However, the UK Biobank had a response rate of 5.5% and concerns have been raised about the generalisability of non-genetic associations from very unrepresentative cohorts¹³.

In summary, walking pace has been found to be associated with reduced risk of all-cause and cause-specific mortality in a number of cohort studies but the literature on the whole has not addressed independence from total PA robustly. There remains a knowledge gap about the independence of the relationships between walking pace and mortality outcomes in large population cohorts.

Our aim was to examine the associations between self-reported walking pace with all-cause, CVD and cancer mortality in a population representative sample of 11 pooled population

British cohorts. A secondary aim was to better understand the role of total and total PA, sex, age, and BMI as potential moderators of these associations.

METHODS

Sample

The Health Survey for England (HSE)¹⁴ and the Scottish Health Survey (SHeS)¹⁵ are established household-based population surveillance studies running since 1991 and 1995, respectively. Each year samples are selected using a multistage, stratified probability design aimed at recruiting a nationally representative sample of adults living in private households. Trained interviewers visited the selected households, and the recruited participants were administered the study questionnaires. 91.6% of survey participants gave written consent to have their death flagged on the NHS Central Mortality Register. For this analysis we used data from HSE 1994, 1997, 1998, 1999, 2003, 2004, 2006 and 2008 and SHeS 1995, 1998 and 2003. As population mortality rates increase evidently from the 4th decade of life, we included individuals aged ≥ 30 years old who reported at least one occasion of walking in the last four weeks, had no doctor-diagnosed or self-reported (long standing illness module) ischemic heart disease, angina, or stroke, and no prevalent cancer through cancer registration records or self-reported (long standing illness module). An occasion of walking was variously defined as at least 10 minutes or at least 15 minutes or at least 30 minutes in the different baseline surveys¹⁶. Each baseline survey was approved by the relevant Research Ethics Committees in England and Scotland.

Mortality outcomes

Participants were followed up for mortality until 31/12/2009 (SHeS) or 31/03/2011 (HSE). Diagnoses for primary causes of death were recorded according to the International Classification of Diseases, Ninth Revision (ICD9) and Tenth Revision (ICD10). Cancer deaths were identified using ICD9 140.0-239.9 and ICD10 C00.0-D48.9 codes; CVD deaths were identified using ICD9 390.0-459.9 and ICD10 I01.0-I99 codes.

Assessment of walking and other physical activity

PA was assessed using an interviewer-administered questionnaire that inquired about walking, domestic PA, and participation in sports and exercises in the four weeks prior to the interview¹⁶. Walking was assessed using a question on number of days walked in the last 4 weeks, the average amount of time spent walking on each day, and the usual walking pace (“which of the following describes your usual walking pace: slow pace, average pace, fairly brisk pace, fast pace-at least 4mph”). Because some baseline surveys (HSE 1994/1999/2003/2004; SHeS 1995) did not enquire about walking duration per reported occasion we imputed this information based on the age and sex-specific estimates of HSE 1997/1998 (that included duration questions) using methods described elsewhere¹⁷. All PA variables were summarized to reflect weekly averages for easier comparison with currently recommended amounts. The criterion validity of the walking-related questions is unknown. In a convergent validity study of over 2000 adults, the Spearman correlation coefficients between accelerometry counts and walking of brisk/fast pace were 0.35 (95% confidence interval (CI): 0.31, 0.40) for women and 0.28 (95%CI: 0.23, 0.34) for men¹⁸. The equivalent coefficients for total weekly questionnaire derived Metabolic Equivalents (MET)-minutes were 0.41 (95%CI: 0.36, 0.46) for women and 0.32 (95%CI: 0.26, 0.38) for men¹⁸.

The PA compendium¹⁹ was used to assign the MET for all PAs to calculate total MET-hours/week. We estimated adherence to the general guideline²⁰ as accumulating weekly at least 150 minutes of moderate intensity or 75 minutes of vigorous intensity or equivalent combinations of moderate and vigorous PA²⁰. We also calculated highest physical activity intensity reached on at least one occasion over the last four weeks that the PA questionnaire time frame covered (light/moderate/vigorous).

Covariates

Height and weight were measured by the interviewers using standard protocols^{14 15}; body mass index (BMI) was calculated as weight (in kilograms) divided by height (in meters) squared. Additional questions assessed age, educational attainment (age completed full time education), presence of longstanding illness, weekly frequency of alcohol consumption, smoking habits (never smoker, ex-smoker, currently smoking 1-9 cigarettes/day, currently smoking 10-19/day, currently smoking ≥ 20 /day), psychological distress/depression (12-point General Health Questionnaire score, GHQ), total (non-walking) leisure time PA volume (MET-hours/week) and total walking volume (MET-hours/week), and highest PA intensity reached on at least one occasion.

Statistical analysis

Analyses were conducted using SPSS version 22 (SPSS, Inc). Cox proportional-hazard models with time in study as the time-scale were used to examine the associations between walking pace and all-cause, CVD, and cancer mortality with “slow pace” as the reference category. Walking pace was originally entered in its original 4 categories format but the low number of events in the “fast pace” category resulted in unstable estimates and broad 95%

CIs; for this reason, all main analyses were carried out with “fairly brisk” and “fast” pace categories collapsed into one group. In a supplemental analysis we entered walking pace in its original format.

Kaplan Meier log-minus-log plots were used to examine the proportional-hazards assumption and no violations were observed. Analyses were adjusted for age, sex, and all covariates listed above. Occupational PA could not be used in the calculation of PA volume because of its non-quantitative nature (it was reported as very/fairly/not very/not at all physically active). Also, we chose not to adjust for occupational PA level in the main Cox models because of the large number of missing values ($n \approx 27,000$) due to the corresponding question missing from SHeS 1995 and for responses being dependant on employment status.

We examined effect modification by sex, age, and total PA level using Type 3 Wald chi-square statistics for the interaction term in the partially adjusted (for age, sex, and cohort/year) model. For interactions with $p < 0.010$ we performed stratified analyses²⁰. To minimize the possibility of spurious associations due to occult disease we ran a sensitivity analysis where we both included and excluded participants who died in the first 24 months of follow-up. This manuscript adheres to the STROBE standards for reporting of observational studies.

RESULTS

In total, 65,381 participants were initially considered; 4,811 participants (8.4% of total eligible) did not consent to follow up and were excluded. The variables with the highest number of missing data were BMI ($n=6,346$), GHQ score ($n=2,444$) and smoking ($n=151$). In total, there were 3617 deaths from any cause including 1014 from CVD and 1276 from

cancer causes. The mean follow up was 9.2 (SD=4.6) years, corresponding to 469,235 person years. **Table 1** presents the sample characteristics for the 50,225 individuals in the analytical sample. Slower walking pace was associated with older age, female sex, higher BMI scores, reporting a long-standing illness at baseline, and indications of psychological distress. Faster walking pace was associated with being a smoker, high frequency of alcohol consumption, finishing education after age 19 years, meeting the PA recommendations, participating in higher intensity PA, high volumes of total non-occupational PA, and higher frequency and total walking volume. Walking pace (in its original 4-group format) showed low magnitude correlations with total leisure time PA volume (Spearman $\rho=0.25$) and walking volume ($\rho=0.20$).

Table 2 presents the associations between walking pace and the three mortality outcomes with all participants who had an event in the first 24 months of the follow-up excluded ($n=49,731$). In the fully adjusted models, walking at an average pace was associated with a risk reduction for ACM of 20% (95%CI:12-28%) compared with those walking at a slow pace. The respective risk reduction for those walking at brisk/fast pace was 24% (13-33%). For CVD mortality, walking at an average pace was associated with a 24% (9-36%) risk reduction and walking at a brisk/fast pace was associated with 21% (1-38%) risk reduction compared with those walking at a slow pace. There was no evidence to suggest walking at an average or brisk/fast pace was associated with a significant risk reduction in cancer mortality (hazard ratio (HR)=1.08 (0.89-1.31) and HR=1.02 (0.81-1.29) respectively). The results were similar in direction and magnitude when those who had an event in the first 24 months were included (**Supplemental Table 1**). When the walking pace variable was entered in its original 4-group format (**Supplemental Table 2**) associations were similar in magnitude and direction but likely due to lower number of events, the 95% CI of the fast pace group were

very wide and included 1 for all three outcomes. Repeating all above analyses with the models adjusted for total duration of MVPA and light intensity activity (instead of average MET-hours per week) produced almost identical results, for example the HR(95%CI) for ACM in the average pace group changed from 0.80 (0.72 to 0.88) to 0.80 (0.73 to 0.88); in the brisk/fast group it changed from 0.76 (0.67, 0.87) to 0.77 (0.68, 0.88) (data available on request).

There were statistically significant interaction effects of walking pace and total PA volume (e.g. $p=0.038$ for ACM) and highest intensity reached (e.g. $p=0.004$ for ACM). Significant interaction effects were also found for walking pace and age (e.g. $p=0.005$ for ACM) but not for sex or BMI.

Stratified analyses by age in two and three groups are presented in Figure 1 and Supplemental Figure 1 respectively, and by compliance with the PA recommendations in Figure 2. Figure 1 shows clearer evidence of a relationship between walking pace and all-cause and CVD mortality, but not cancer mortality, in the over 50s compared to the results for the whole sample. There was little evidence of association in the under 50s. Supplemental Figure 1 showed clearer evidence for a relationship of walking pace with all-cause mortality in those aged 45-59 and ≥ 60 years and with CVD mortality in those aged ≥ 60 years.

Figure 2 shows clearer evidence of a relationship between walking pace and all-cause and CVD mortality, but not cancer mortality, amongst those that did not meet the PA guidelines compared to the results of the whole sample. For those meeting the guidelines, the direction of effect for all cause and CVD mortality was protective for increasing pace, but very low number of events caused low power and wide confidence intervals.

Figure 3 shows the stratified analyses of walking pace and all-cause and CVD mortality by highest intensity reached; analyses were not performed for cancer mortality due to the low number of events in some cells and the apparent violation of the proportional hazards assumption. There was evidence of a relationship between walking pace and ACM in both the light and moderate intensity groups. There was some evidence for a relationship with CVD mortality in these groups although confidence intervals were wider and there was no dose-response. There was no evidence of a relationship between walking pace and all-cause or CVD mortality amongst the group that reported reaching vigorous intensity.

DISCUSSION

In adults in Scotland and England, walking at average or brisk/fast pace was associated with a reduced risk of all-cause and CVD mortality compared with walking at slow pace. However, there was no evidence of a similar relationship with cancer mortality. Our findings are in agreement with previous studies which have reported that a higher pace of walking was associated with a risk reduction for ACM of between 19%²¹ and 42%¹¹. Our estimates are within this range, and adjusted for total volume of both walking and non-walking PA (MET-hrs/week), and highest PA intensity reached. We found that the associations between pace and ACM persisted after controlling for total leisure time PA which is consistent with studies that controlled for total walking energy expenditure²² and moderate to vigorous PA¹². Batty et al., reported a 20% reduction in cancer mortality for walking fast.¹¹ Similar to Yates et al., (2017)¹² we did not find any evidence of this effect.

Possible explanations

The association between pace on all-cause and CVD mortality may be explained by the increased relative exercise intensity elicited by a faster pace providing a greater stimulus for physiologic adaptations²³ in functions known to influence CVD mortality. This may be further confirmed by the observation that the associations of walking pace with ACM and (in particular) CVD mortality were considerably weakened for the subsample of participants that have achieved vigorous intensity in non-walking physical activity.

We did not find an effect of pace on cancer mortality. Volume may be more important than pace for cancer mortality. Alternatively we know that different cancers have different relationships with PA, and that if we had examined mortality from specific malignancies e.g., breast and colon cancer a relationship may have been observed²⁴.

We did not find evidence for associations for the younger participants, the physically active, or for those reaching vigorous intensity, but recommend caution when interpreting these findings. Low number of events in strata increased uncertainty. It is possible that older age and lower PA status (total or intensity) predict lower aerobic fitness (maximal oxygen consumption). As such, that the relative intensity of walking at faster pace may be equivalent to the upper end of moderate intensity or even vigorous intensity, and therefore provides a greater physiological stimulus for maintaining cardiovascular function and promoting health.

Separating the effect of one specific aspect of physical activity and understanding its potentially causal association with mortality is complex. Our analyses suggest that participants who usually walk at a brisk/fast pace are overall the most active and probably the healthiest. Although it is biologically plausible that walking at a higher pace leads to better health overall and cardiovascular health specifically, it is also likely that walking at a faster

pace is a marker for better health, fitness, and physical function, which predicts the risk for mortality in the following years. In other words, walking pace may be a predictor of lower mortality risk, a causal factor, or a both.

Strengths and limitations

The strengths of the present study include the large sample comprising a series of baseline surveys that were roughly representative of the population in England and Scotland, the very high response rates, and the relatively long follow up. The results can be generalised to the UK population with more confidence than previous estimates. To our knowledge this is the first such study to report associations between walking pace and all-cause, CVD, and cancer mortality and adjust for total (walking and non-walking) PA volume and highest intensity reached. We also present novel analysis of associations stratified by age, total PA and highest intensity reached to investigate important potential effect modifiers.

Limitations include the exposure “walking pace” and all other PA variables were self-reported and therefore subject to misclassification and other biases. Further misclassification may have been introduced by the imputation of walking duration for a number of baseline surveys¹⁷, and this may be partly the reason why adjustments for total walking volume had negligible impact on the estimates. The repeated cross-sectional nature of HSE and SHeS meant we could not assess or account for temporal changes in walking behavior within individuals. The analyses controlled for a comprehensive set of covariates in addition to PA, although we cannot discount the possibility of residual confounding. Some stratified analyses had too few events and therefore may not have been powerful enough to detect associations or lack of association with confidence.

Implications and future research

The additional protective effect demonstrated from higher walking pace may have implications for public health messaging. Walking is a cornerstone of PA promotion for public health, but volume of walking (steps per day) has often been emphasised. Given the perceived time barrier cited by those who fail to meet current PA guidelines²⁵, a pace change could be more feasible (for those with adequate physical capacity) than increased volume or duration. We encourage the Chief Medical Officers' Physical Activity Guidelines Committee to consider this in their upcoming revision of the PA Guidelines. Further experimental research is warranted to establish if a randomised intervention based on pace elicits important physiological change²⁶.

Conclusions

Walking is known to benefit health. Assuming causal relationships, these analyses suggest that increasing walking pace could be linked with lower risk for all-cause and CVD mortality. Walking pace should be emphasised in public health messages, especially in circumstances when increase in walking volume or frequency is less feasible.

ACKNOWLEDGEMENTS & FUNDING

This analysis was not financially supported directly by any individual, agency, or institution. The harmonization of the pooled datasets used in this analysis was funded by the National Institute for Health Research (UK) through a grant to ES. ES and DD are funded by the National Health and Medicine Research Council (Australia) through a Senior Research Fellowship and an Early Career Research Fellowship, respectively.

FIGURE LEGENDS

Figure 1: Associations between walking pace (3 groups) and all-cause, cardiovascular disease, and cancer mortality by age group (<50 vs. ≥50 years)^a. Walkers aged 30 years and over with no diagnosed cardiovascular disease or cancer at baseline^b. The Health Survey for England and Scottish Health Survey.

50 years of age was selected as a cutoff point due to its proximity to median age for this sample (48 years)^b Prevalent cardiovascular disease was defined as doctor-diagnosed or self-reported (long standing illness module) ischemic heart disease, angina, or stroke; prevalent cancer was determined through cancer registration records or self-reported (long standing illness module)^cModel adjusted for sex, cohort, long-standing illness, alcohol drinking frequency, psychological distress, body mass index, smoking status, education level, total (non-walking) physical activity volume (MET-hrs/week), walking volume (MET-hrs/week), and highest physical activity intensity reached.

Figure 2: Associations between walking pace (3 groups) and all-cause, cardiovascular disease, and cancer mortality, by physical activity level (meeting vs. not meeting the physical activity recommendations).^a Walkers aged 30 years and over with no diagnosed cardiovascular disease or cancer at baseline^b. The Health Survey for England and Scottish Health Survey.

^a Adherence to the physical activity recommendations was defined as at least 150 minutes of moderate-intensity activity or 75 minutes per week of vigorous intensity activity or equivalent combinations of moderate and vigorous activity^b Prevalent cardiovascular disease was defined as doctor-diagnosed or self-reported (long standing illness module) ischemic heart disease, angina, or stroke; prevalent cancer was determined through cancer registration records or self-reported (long standing illness module)^cModel adjusted for sex, cohort, long-standing illness, alcohol drinking frequency, psychological distress, body mass index, smoking status, education level, walking volume (MET-hrs/week), highest physical activity intensity reached.

Figure 3: Associations between walking pace (3 groups) and all-cause, and cardiovascular disease mortality, by highest physical activity intensity reached (light/moderate/vigorous). Walkers aged 30 years and over with no diagnosed cardiovascular disease or cancer at baseline^a. The Health Survey for England and Scottish Health Survey.

^a Prevalent cardiovascular disease was defined as doctor-diagnosed or self-reported (long standing illness module) ischemic heart disease, angina, or stroke; prevalent cancer was determined through cancer registration records or self-reported (long standing illness module)^bModel adjusted for sex, cohort, long-standing illness, alcohol drinking frequency, psychological distress, body mass index, smoking status, education level, walking volume (MET-hrs/week), and total (non-walking) physical activity volume (MET-hrs/week).

Table 1. Baseline characteristics of the sample by walking pace. Walkers aged 30 years and over with no diagnosed cardiovascular disease or cancer at baseline. The Health Survey for England and Scottish Health Survey (n=50,225).

	Walking Pace				
	Slow Pace	Average Pace	Fairly Brisk Pace	Fast Pace	
					<i>P^e</i>
Age, mean (SD) (years)	57.8	51.1	47.7	44.6	<0.001
Sex (% female)	61.0	58.5	52.2	40.5	<0.001
Body mass index, mean (SD) (kg/m ²)	28.6 (5.7)	27.3 (4.7)	26.1 (4.1)	25.5 (3.9)	<0.001
Long standing illness ^a (%)	64.6	41.9	35.4	33.0	<0.001
Smoking (% current)	23.9	24.0	21.5	27.5	<0.001
Alcohol frequency (% ≥5 times/week) ^b	18.7	18.7	22.4	24.5	<0.001
Psychological distress (% with General Health Questionnaire score ≥4) ^c	20.1	11.9	11.6	12.2	<0.001
Age finished education (% finished age 19+)	12.9	18.1	26.3	29.0	<0.001
Meeting the physical activity recommendations ^d	8.9	17.2	47.5	52.4	<0.001
Highest PA intensity reached (%)					
No physical activity	11.7	7.9	4.9	4.9	<0.001
Light intensity only	63.4	52.5	14.4	14.8	
Reached moderate intensity	11.8	15.3	42.9	37.2	
Reached vigorous intensity	13.1	24.3	37.7	43.0	
MET-hours of physical activity per week, median (SE)	8.0 (0.38)	17.0 (0.20)	23.1 (0.31)	32.0 (0.80)	<0.001
Number of days walked per week, median (SE)	2.0 (0.04)	2.5 (0.02)	2.5 (0.02)	3.0 (0.05)	<0.001
MET-hours of walking per week (any pace), median (SE)	2.3.5 (0.12)	4.9 (0.08)	6.1 (0.12)	9.4 (0.39)	<0.001

^aDichotomous variable derived from responses to a series of questions (yes/no) on illness within 8 listed body systems (eg. nervous system, digestive system, heart and circulatory system etc.). At least one illness required to have longstanding illness;^b derived from the question “on how many days in the last 7 days did you have an alcoholic drink; ^c General Health Questionnaire comprises 12 questions related to psychological health (eg. concentration, feeling depressed etc) the categories were 0, 1-3 and ≥ 4 ; ^d at least 150 minutes of moderate-intensity activity or 75 minutes per week of vigorous intensity activity or equivalent combinations of moderate and vigorous activity;); ^e P-value calculated using Kruskal-Wallis test for continuous variables and likelihood ratio chi-square test for categorical variables.

Table 2: Associations between walking pace (3 groups) and all-cause, cardiovascular disease, and cancer mortality. Walkers aged 30 years and over with no diagnosed cardiovascular disease or cancer at baseline^a excluding deaths occurring the first 24 months of follow up. The Health Survey for England and Scottish Health Survey (n=49,731).

	Deaths/n	Model 1 ^b		Model 2 ^c		Model 3 ^d	
		HR	95% CIs	HR	95% CIs	HR	95% CIs
All-cause Mortality							
<i>Walking Pace</i>							
Slow	576/4101	1		1		1	
Average	1957/25857	0.73	0.67,0.81	0.78	0.71,0.87	0.80	0.72,0.88
Brisk/Fast	730/19773	0.61	0.55,0.69	0.68	0.61,0.77	0.76	0.67,0.87
<i>P trend linear</i>		<0.001		<0.001		<0.001	
<i>P trend nonlinear</i>		<0.001		0.003		0.001	
Cardiovascular Mortality							
<i>Walking Pace</i>							
Slow	192/4101	1		1		1	
Average	552/25857	0.68	0.57,0.81	0.75	0.63,0.90	0.76	0.64,0.91
Brisk/Fast	193/19773	0.55	0.45,0.68	0.67	0.54,0.83	0.79	0.62, 0.99
<i>P trend linear</i>		<0.001		0.001		0.089	
<i>P trend nonlinear</i>		0.007		0.032		0.007	
Cancer Mortality							
<i>Walking Pace</i>							
Slow	137/4101	1		1		1	
Average	717/25857	1.03	0.85,1.24	1.06	0.88,1.29	1.08	0.89,1.31
Brisk/Fast	297/19773	0.88	0.71,1.08	0.95	0.76, 1.17	1.02	0.81,1.29
<i>P trend linear</i>		0.152		0.478		0.945	
<i>P trend nonlinear</i>		0.338		0.269		0.339	

^a Prevalent cardiovascular disease was defined as doctor-diagnosed or self-reported (long standing illness module) ischemic heart disease, angina, or stroke; prevalent cancer was determined through cancer registration records or self-reported (long standing illness module) ^bModel adjusted for age, sex, and cohort; ^cModel also adjusted for long-standing illness, alcohol drinking frequency, psychological distress, body mass index, smoking status, education

level; ^dModel also adjusted for total (non-walking) physical activity volume (MET-hrs/week), walking volume (MET-hrs/week), and highest physical activity intensity reached.

REFERENCES

1. Kelly P, Murphy M, Mutrie N. The Health Benefits of Walking. Walking: Connecting Sustainable Transport with Health: Emerald Publishing Limited 2017:61-79.
2. Hamer M, Chida Y. Walking and primary prevention: a meta-analysis of prospective cohort studies. *Br J Sports Med* 2008;42(4):238-43. doi: bjsm.2007.039974 [pii] 10.1136/bjsm.2007.039974 [published Online First: 2007/12/01]
3. Woodcock J, Franco OH, Orsini N, et al. Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. *Int J Epidemiol* 2011;40(1):121-38. doi: 10.1093/ije/dyq104 dyq104 [pii] [published Online First: 2010/07/16]
4. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose-response meta-analysis of cohort studies. *Int J Epidemiol* 2011;40(5):1382-400. doi: 10.1093/ije/dyr112 dyr112 [pii] [published Online First: 2011/11/01]
5. Kelly P, Kahlmeier S, Götschi T, et al. Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. *International journal of behavioral nutrition and physical activity* 2014;11(1):132.
6. Office for National Statistics (UK). Avoidable mortality in England and Wales: 2015 2017 (accessed January 19th 2018) [Available from: <https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/causesofdeath/bulletins/avoidablemortalityinenglandandwales/2015>.
7. Celis-Morales CA, Lyall DM, Welsh P, et al. Association between active commuting and incident cardiovascular disease, cancer, and mortality: prospective cohort study. *Bmj* 2017;357:j1456. doi: 10.1136/bmj.j1456
8. Matthews CE, Jurj AL, Shu XO, et al. Influence of exercise, walking, cycling, and overall nonexercise physical activity on mortality in Chinese women. *American journal of epidemiology* 2007;165(12):1343-50. doi: 10.1093/aje/kwm088 [published Online First: 2007/05/05]
9. Saevereid HA, Schnohr P, Prescott E. Speed and Duration of Walking and Other Leisure Time Physical Activity and the Risk of Heart Failure: A Prospective Cohort Study from the Copenhagen City Heart Study. *PLoS ONE* 2014;9(3):e89909. doi: 10.1371/journal.pone.0089909
10. Manson JE, Greenland P, LaCroix AZ, et al. Walking compared with vigorous exercise for the prevention of cardiovascular events in women. *New England Journal of Medicine* 2002;347(10):716-25.
11. Batty GD, Shipley MJ, Kivimaki M, et al. Walking pace, leisure time physical activity, and resting heart rate in relation to disease-specific mortality in London: 40 years follow-up of the original Whitehall study. An update of our work with professor Jerry N. Morris (1910–2009). *Annals of epidemiology* 2010;20(9):661-69.
12. Yates T, Zaccardi F, Dhalwani NN, et al. Association of walking pace and handgrip strength with all-cause, cardiovascular, and cancer mortality: a UK Biobank observational study. *European Heart Journal* 2017
13. Ebrahim S, Davey Smith G. Commentary: Should we always deliberately be non-representative? *International Journal of Epidemiology* 2013;42(4):1022-26. doi: 10.1093/ije/dyt105
14. Mindell J, Biddulph JP, Hirani V, et al. Cohort Profile: The Health Survey for England. *International Journal of Epidemiology* 2012;41(6):1585-93. doi: 10.1093/ije/dyr199
15. Gray L, Batty GD, Craig P, et al. Cohort profile: the Scottish health surveys cohort: linkage of study participants to routinely collected records for mortality, hospital discharge, cancer and offspring birth characteristics in three nationwide studies. *International journal of epidemiology* 2010;39(2):345-50.

16. Stamatakis E, Ekelund U, Wareham NJ. Temporal trends in physical activity in England: The Health Survey for England 1991 to 2004. *Preventive Medicine* 2007;45(6):416-23. doi: <http://dx.doi.org/10.1016/j.ypmed.2006.12.014>
17. Stamatakis E, Ekelund U, Wareham NJ. Temporal trends in physical activity in England: the Health Survey for England 1991 to 2004. *Prev Med* 2007;45(6):416-23. doi: 10.1016/j.ypmed.2006.12.014 [published Online First: 2007/02/24]
18. Scholes S, Coombs N, Pedisic Z, et al. Age-and sex-specific criterion validity of the health survey for England Physical Activity and Sedentary Behavior Assessment Questionnaire as compared with accelerometry. *Am J Epidemiol* 2014;179(12):1493-502.
19. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of Physical Activities: A Second Update of Codes and MET Values. *Medicine & Science in Sports & Exercise* 2011;43(8):1575-81 10.249/MSS.0b013e31821ece12.
20. World Health Organization. Global Recommendations on Physical Activity for Health. Geneva: WHO 2010.
21. Stanaway FF, Gnjdjic D, Blyth FM, et al. How fast does the Grim Reaper walk? Receiver operating characteristics curve analysis in healthy men aged 70 and over. *Bmj* 2011;343:d7679. doi: 10.1136/bmj.d7679
22. Williams PT, Thompson PD. The Relationship of Walking Intensity to Total and Cause-Specific Mortality. Results from the National Walkers' Health Study. *PLoS ONE* 2013;8(11):e81098. doi: 10.1371/journal.pone.0081098
23. McArdle WD, Katch FI, Katch VL. Exercise Physiology. Energy, Nutrition and Human Performance. 5th ed. Baltimore: Lippincott Williams & Wilkins 2001.
24. McTiernan A. Mechanisms linking physical activity with cancer. *Nature Reviews Cancer* 2008;8(3):205.
25. European Commission. Special Eurobarometer 412. Sport and physical activity. Brussels: DG COMM "Strategy, Corporate Communication Actions and Eurobarometer" Unit, 2015.
26. Duncan JJ, Gordon NF, Scott CB. Women walking for health and fitness. How much is enough? *Jama* 1991;266(23):3295-9. [published Online First: 1991/12/18]